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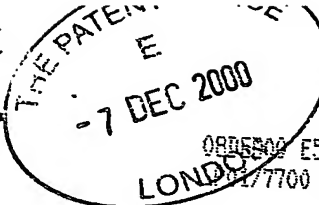
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Embedding Data in Material

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Embedding Data in Material

The present invention relates to Embedding Data in Material. Embodiments of the invention relate to Watermarking.

In this specification, "material " means any one or more of video material, audio material and data material. "Video" is generic to still and moving images.

Steganography

Steganography is the embedding of data into material such as video material, audio material and data material in such a way that the data is imperceptible in the material.

10 Data may be embedded as a watermark in material such as video material, audio material and data material. A watermark may be imperceptible or perceptible in the material.

A watermark may be used for various purposes. It is known to use watermarks for the purpose of protecting the material against, or trace, infringement of the intellectual property rights of the owner(s) of the material. For example a watermark may identify the owner of the material.

Watermarks may be "robust" in that they are difficult to remove from the material. Robust watermarks are useful to trace the provenance of material which is processed in some way either in an attempt to remove the mark or to effect legitimate processing such as video editing or compression for storage and/or transmission. Watermarks may be "fragile" in that they are easily damaged by processing which is useful to detect attempts to remove the mark or process the material.

Visible watermarks are useful to allow e.g. a customer to view an image e.g. over the Internet to determine whether they wish to buy it but without allowing the customer access to the unmarked image they would buy. The watermark degrades the image and the mark is preferably not removable by the customer. Visible watermarks are also used to determine the provenance of the material into which they are embedded.

It is known to conceal a watermark in material in which the mark is embedded dependent on the data content of the material. It is desirable to minimise any changes to the material needed to embed the data in it to avoid degrading the material.

According to one aspect of the present invention, there is provided a method of embedding data in material, comprising the steps of:

producing transform coefficients C_i of the material;

comparing the magnitudes of the coefficients with a threshold value T ; and

5 producing, from the coefficients C_i and the said data modified, coefficient values C_i' which are modified by respective information symbols of a pseudo random symbol sequence modulated by the said data to be embedded;

wherein the said step of producing modified coefficient values does not use coefficients of magnitude greater than the said threshold T and does not use the
10 corresponding information symbols.

The data is detected at a decoder by correlating a pseudo random symbol sequence with the material in which the data is embedded. The data is represented by the sign of the correlation function. By not using, during embedding, coefficients which have a value greater than the threshold, any changes necessary to alter the
15 coefficients to achieve the appropriate sign of the correlation value to represent a bit of the concealed data are minimised.

According to another aspect of the present invention, there is provided a method for detecting data embedded in material, the detecting method comprising

receiving transform coefficients of the material;

20 comparing the magnitudes of the received coefficients with a threshold value T ; and

correlating, the said coefficients with a respective symbols of a pseudo random symbol sequence to detect the said data, wherein the correlating step does not use coefficients of magnitude greater than the said threshold T and corresponding symbols
25 of the pseudo random symbol sequence.

Thus the detecting method is complementary to the embedding method.

The invention also provides the following aspects a), and b):

a) Apparatus for embedding data in material comprising a transformer for producing transform coefficients C_i of the material;

30 a comparator for comparing the magnitudes of the coefficients with a threshold value T ; and

a combiner for producing, from the coefficients C_i and the said data, modified coefficient values C_i' which are modified by respective information symbols of a pseudo random symbol sequence modulated by the said data to be embedded, wherein the combiner does not use coefficients of magnitude greater than the said threshold T and does not use the corresponding information symbols;

b) Apparatus for detecting data embedded in material comprising an input for receiving transform coefficients of the material;

a comparator for comparing the magnitudes of the received coefficients with a threshold T ; and

a correlator for correlating, the said coefficients with respective symbols of a pseudo random symbol sequence to detect the said data, wherein the correlation does not use coefficients of magnitude greater than the said threshold T and the corresponding symbols of the pseudo random symbol sequence.

According to a further aspect of the invention, there is provided a method of detecting data embedded in material, the method comprising;

receiving transform coefficients of the material;

comparing the magnitudes of the received coefficients with a threshold T_{clip} ;

clipping, to a magnitude T_{clip} , the magnitude of coefficients of magnitude greater than the said threshold T_{clip} ; and

correlating the clipped and unclipped coefficients with a pseudo random symbol sequence to detect data embedded in the material.

Apparatus according to the further aspect for detecting data embedded in material, comprises;

an input for receiving transform coefficients C_i' of the material;

a comparator for comparing the magnitudes of the received coefficients with a threshold T_{clip} ;

means for clipping, to a magnitude T_{clip} , the magnitude of coefficients of magnitude greater than the said threshold T_{clip} ; and

a correlator for correlating the clipped and unclipped coefficients with a pseudo random symbol sequence to detect data embedded in the material.

This further aspect of the invention may involve only the detecting method and operates independently of the embedding method. By clipping large value coefficients

to a preset smaller value, such coefficients no longer dominate the value of the correlation function needed to decode the embedded data.

However, preferably, there is provided:

- 5 a) A method of embedding data in material, the method comprising receiving transform coefficients C_i representing the material; comparing the magnitudes of the said transform coefficients C_i with a threshold T_{clip} ; clipping, to the magnitude T_{clip} , the magnitudes of those of the coefficients having a magnitude exceeding T_{clip} to produce clipped coefficients; and
- 10 producing modified coefficients C_i' of values dependent on a scaling factor and the data to be embedded, and the scaling factor is calculated using the said clipped coefficients and the coefficients C_i of magnitude less than T_{clip} .

- b) Apparatus for embedding data in material, the apparatus comprising: an input for receiving transform coefficients C_i representing the material;
- 15 a comparator for comparing the magnitudes of the said transform coefficients with a threshold T_{clip} ;
- a clipper for clipping, to the magnitude T_{clip} , the magnitudes of those of the coefficients having a magnitude exceeding T_{clip} ; and
- a processor for producing modified coefficients C_i' of values dependent on a scaling factor and the data to be embedded, and the scaling factor is calculated using
- 20 the said clipped coefficients and the coefficients C_i of magnitude less than T_{clip} .

Thus by clipping large value coefficients to a smaller value such coefficients no longer dominate the value of the function used to calculate the scaling factor.

- The invention also provides a computer program product arranged to carry out
- 25 one of the aforesaid methods when run on a computer.

For a better understanding of the present invention, reference will now be made by way of example to the accompanying drawings in which:

Figure 1 is a schematic block diagram of an illustrative watermarking system according to the present invention;

- 30 Figure 2 is a schematic diagram of a wavelet transform showing the relationship of the bits of a pseudo random binary sequence (PRBS) to transform coefficients ;

Figure 3 is a flow diagram of calculations performed by the embedder of Figure 1;

Figure 4A is a flow diagram of a modification, in accordance with one embodiment of the present invention, of the flow diagram of Figure 3;

5 Figure 4B is a diagram showing the relationship of coefficients C_i and symbols P_i of a pseudo random symbol sequence;

Figure 5 is a schematic block diagram of an illustrative watermark decoding and removal system;

10 Figure 6 is a flow diagram of calculations performed by the watermark remover and decoder of Figure 5;

Figure 7 is a flow diagram of a modification, in accordance with one embodiment of the present invention, of the flow diagram of Figure 6;

Figure 8 is a flow diagram of a modification, in accordance with another embodiment of the present invention, of the flow diagram of Figure 6;

15 Figures 9 and 10 are diagrams explaining background to wavelet transforms; and

Figures 11 and 12 are diagrams showing a UMID and a data reduced UMID.

Overview

Referring to Figure 1, in the shown illustrative watermarking system, a spatial
20 domain image I produced by a source 1 is combined with a watermark, which in this example is data of a UMID produced by a UMID generator 6. In this example the image is a luminance image. The image could be a color image. In this example the watermark is imperceptible. UMIDs are described in the section *UMIDs* below. The image is subjected to a wavelet transform T . Wavelet transforms are briefly discussed
25 in the section *Wavelets* below. The data of the UMID is combined with the wavelet coefficients in an embedder 3 in the manner described in detail in the following text. The transformed image together with the watermark is subjected to an inverse wavelet transform T^{-1} to produce a spatial domain watermarked image.

30 The watermark is decoded and, optionally, removed from the watermarked image using the illustrative decoding and removal system of Figure 5.

Pseudo Random Symbol Sequence (PRBS).

Referring to Figures 1 and 2, a PRBS generator 4 is provided. The PRBS generator 4 comprises a first generator 4₁ and a converter 4₂ which generate a pseudo random symbol sequence (PRBS). The generator 4₁ produces a pseudo random binary sequence which is pseudo random because the sequence whilst appearing random can be reliably reproduced. The sequence has a length of J x L symbols where there are J bits of watermark data W1.....WJ.. The symbols of the sequence are denoted herein by P_i, where i denotes the ith symbol of the sequence. The converter 4₂ converts the binary 1 and 0 to +1 and -1 respectively to produce the pseudo random symbol sequence (PRBS) P_i of values +1 and -1.

Referring to Figure 2, for the purposes of explanation, it is assumed that the wavelet transform applied to the original spatial domain image results in a transform having four sub-bands of level 1: see the section *Wavelets* below. For ease of explanation the following description will refer only to the upper horizontal sub-band, but it will be appreciated that the present invention can be applied to any sub-band and may be applied to a plurality of sub-bands. The coefficients of the wavelet transform are denoted by C_i where C_i is the ith coefficient of a sequence of J x L coefficients corresponding to the symbols P_i of the PRBS. Watermark data bit W_j is embedded in coefficients C_i for i = (j-1)L + 1, to jL.

Embedder

The embedder 3 shown schematically in Figure 1A operates in accordance with the flow diagram of Figure 3. The embedder calculates a function

$$C_i' = C_i + \alpha_j P_i$$

where C_i' is an ith wavelet coefficient modified to encoded a bit W_j of watermarking data; and

α_j is a parameter the value of which depends on:

a) the value 1 or 0 of a bit W_j of the UMID to be encoded in a modified coefficient C_i'; and

b) the sign of a correlation value S_j = ΣC_i.P_i, where the sum is taken over the range i = (j-1)L + 1, to jL: and

c) an offset value so that α_j = α_j' + offset. The offset is provided to ensure that the correlation at the decoder has the correct sign to represent the bit W_j and to make the watermark more robust against unauthorised removal or removal by subsequent

image processing. The value of the offset is empirically determined to provide robustness yet minimise visibility of the watermark in the image. The offset value currently preferred is +1.

The principle of operation is that a watermark bit $W_j=1$ is encoded as a positive correlation value and $W_j=0$ is encoded as a negative correlation value (or vice versa). α_j is chosen to ensure the value of a correlation $S_j' = \sum C_i' \cdot P_i$ for $i = (j-1)L + 1$, to jL performed *at the decoder* has the correct sign to represent the value of bit W_j . If the correlation S_j performed at the encoder has the correct sign, then $\alpha_j' = 0$ otherwise α_j' is modified to ensure that the correlation S_j' performed at the decoder has the correct sign.

Thus referring to Figure 3:-

The value α_j' equals α_j - offset.

Step S1 calculates the correlation value $S_j = \sum C_i \cdot P_i$, where the sum is taken over the range for $i = (j-1)L + 1$, to jL for a sequence of L coefficients C_i and PRBS symbols P_i . (Note that 'bits' P_i have values +1 and -1 to ensure that bits of value 0 produced by the generator 4_1 contribute to the value of S_j .)

Step S2 determines whether the bit W_j of the UMID to be encoded is 1 or 0. It will be appreciated that the bit W_j is in effect encoded over L coefficients. If $W_j = 1$ then steps S3 to S5 and S9⁺ are followed.

Step S3 determines the sign of the correlation S_j . If the sign is positive and the bit W_j is 1 then
at step S4 $\alpha_j' = 0$.

If the sign determined at step S3 is negative but the bit $W_j = 1$ (which should be encoded by S_j positive), then

at step S5 $\alpha_j' = -S_j/(L-1)$.

Finally at step S9⁺ an offset of magnitude 1 is added to ensure that a positive correlation value results, e.g. when $S_j=0$.

If $W_j=0$ then steps S6 to S8 and S9⁻ are followed.

Step S6 determines the sign of the correlation S_j . If the sign is negative and the bit W_j is 0 then
at step S7 $\alpha_j' = 0$.

If the sign determined at step S6 is positive but the bit $W_j = 0$ (which should be encoded by S_j negative), then

at step S8 $\alpha_j' = -S_j/(L-1)$.

At step S9 the offset of magnitude 1 is subtracted to ensure that a negative correlation value results when e.g. $S_j = 0$.

At step S10 the value $C_i' = C_i + \alpha_j P_i$ is calculated for $i = (j-1)L + 1$, to jL .

It will be noted that the offset is an unsigned magnitude 1 in this example.

In an alternative embodiment, at steps S5 and S8 $\alpha_j = -S_j/L$.

A first embodiment of the invention, Figure 4

10 Threshold on the values of C_i and C_i'

In accordance with an embodiment of the present invention, the values of the coefficients C_i are compared with a threshold value Th_e at the embedder of Figure 1. (As will be described in more detail below, the values of the coefficients C_i' are compared with a threshold value Th_d at the remover and decoder of Figure 5.) If the value of a coefficient exceeds the threshold, that coefficient is not used in establishing the correlation value S_j used in the embedder to determine the value of α_j . (Also if the value of a coefficient exceeds the threshold, that coefficient is not used in establishing the correlation value S_j' used in the remover and decoder to determine the value of α_j and to decide the embedded data.) The thresholds Th_e and Th_d may be equal, but it has been found that Th_d is preferably greater than Th_e .

By way of a simple example, assume that $L=4$ and bits P_1 to P_4 have values $+1, -1, -1$, and $+1$. Then referring to Table 1 three examples are shown.

	P1 C1	P2 C2	P3 C3	P4 C4	S_j, α_j' $W_j=0$
Pi	+1	-1	-1	+1	
Ex1 Ci	-2	-5	+1	-3	-1,0
Ex2 Ci	-2	-25	+1	-3	19, -19/3
Ex3 Ci	-2		+1	-3	-6,0

Table 1

Example 1 (Ex1)

The coefficients C_i have the values shown. If the value of the bit W_j of the watermark to be encoded is 0 then according to Figure 3, $S_j = -1$ and so $\alpha_j' = 0$.

Example 2 (Ex2)

5 If as shown in example 2 the coefficient C_2 has a value -25 then $S_j = +19$ and $\alpha_j' = -19/3$. Large values of α_j' may cause the watermark to be perceptible when it should be imperceptible.

Example 3 (Ex3)

10 In accordance with an embodiment of the present invention, thresholds $+Th_e$ and $-Th_e$ are set. The magnitude of Th_e may be about 6 for the above example. In practice it is set empirically. Thus as shown in Table 1, the coefficient C_2 is not used in the calculation of S_j , and also the corresponding symbol of the PRBS is also not used. As a result $S_j = -6$ and $\alpha_j' = 0$. Thus if the magnitude of a coefficient exceeds the threshold the coefficient is not used.

15 Now, referring to Figure 4A, in accordance with this embodiment, the following procedure takes place at the embedder before step S1 of Figure 3.

At step S40, the magnitude of the coefficient value C_i is compared with the threshold Th_e . If the magnitude of C_i is greater than the threshold Th_e then at step S42 C_i is not used. Otherwise at step S44 C_i is used to calculate C_i' as described with reference to Figure 3. Referring to Figure 4B, it will be recalled that each symbol P_i of the PRBS is associated with a coefficient C_i . When a coefficient C_i is not used because it exceeds the threshold, the corresponding symbol P_i generated by the generator 4 is also not used as indicated by the blocks C_i and P_i in Figure 4B.

Watermark Decoding and Removing System (Figures 5 and 6

25 Referring to Figure 5, the watermark removing and decoding system has an input for receiving a spatial domain watermarked image from the system of Figure 1. The image may have been subject to image processing (not shown) between production by the system of Figure 1 and the receipt by the system of Figure 5.

30 The received image is transformed (T) by a wavelet transformer 6 to produce wavelet coefficients C_i' . The coefficients C_i' are provided to a synchroniser 8 which correlates the coefficients with a PRBS generated by a generator 10 where P_i has a value +1 and -1 representing binary 1 and 0 respectively. The PRBS generated by the

generator 10 is identical to that generated by the generator 4 of the system of Figure 1. The synchroniser 8 and the PRBS 10 carry out, in known manner, correlations with differing shifts of the PRBS relative to the coefficients to determine the position in the watermarked transformed image of the original PRBS produced at the watermarking system of Figure 1. Once synchronisation has been achieved the coefficients C_i' are correlated with the PRBS in another correlator 12 to produce the correlation value

$$S_j' = \sum C_i' \cdot P_i \text{ for } i = (j-1)L + 1, \text{ to } jL \text{ for each of } j = 1 \text{ to } J$$

The correlation value S_j' is provided to a decoder 14 and to a remover 16, the operations of which will be described with reference to the flow diagram of Figure 6. The decoder 14 extracts the UMID from the image. The watermark is removed by the remover 16. The resulting restored transformed image is subject to an inverse wavelet transform (T^{-1}) in an inverse transformer 18.

Referring to Figure 6, the synchronisation of the PRBS with the received transformed image occurs at step S12. At step S14, the correlation value

$$S_j' = \sum C_i' \cdot P_i \text{ for } i = (j-1)L + 1, \text{ to } jL$$

is calculated over the length L of the PRBS.

At step S16, the sign of the value S_j' is determined. If S_j' is negative then the bit of the watermark, (the UMID in this example), is 0. If S_j' is positive the bit of the watermark is 1.

At step S18,

$$\alpha_j' = S_j' / (L-1)$$

is calculated from S_j' . (This calculation may be an approximation because it assumes that $\sum C_i \cdot P_i = 0$)

At step S22, $C_i = C_i' - \alpha_j' P_i$ is calculated for $i = (j-1)L + 1, \text{ to } jL$.

In an alternative embodiment at step S18 $\alpha_j' = S_j' / L$

The first embodiment of the invention, Figure 7

As described above in the section describing Figure 4, at the embedder coefficients C_i of magnitude greater than the threshold value Th_e are not used. Likewise, at the decoder and remover of Figure 5 coefficients C_i' of magnitude greater than the threshold value Th_d are not used. Preferably, Th_d is greater than Th_e : that has been found by experiment to give better results.

Thus referring to Figure 7, the following procedure is carried out before step S14 of Figure 6.

At step S41, the magnitude of the coefficient value C_i' is compared with the threshold Th_d . If the magnitude of C_i' is greater than the threshold Th_d then at step S43 C_i' is not used. Otherwise at step S45 C_i' is used to calculate C_i as described with reference to Figure 6. Referring to Figure 4B, it will be recalled that each symbol P_i of the PRBS is associated with a coefficient C_i' . When a coefficient C_i' is not used because it exceeds the threshold, the corresponding symbol P_i generated by the PRBS generator 10 is not used as indicated by the blocks C_i and P_i in Figure 4B.

10 A second embodiment of the invention, Figure 8

Clipping at the decoder and remover of Figure 5

In an alternative modification, the values of the modified coefficients C_i' are clipped at the decoder and remover of Figure 5 if they exceed a threshold of magnitude T_{clip} . (Step S80). Thus coefficient values greater than the threshold are reduced to a predetermined value e.g. T_{clip} . For example referring to Table 1 Example 2, the coefficient C_2 (-25) is clipped to say $T_{clip} = -6$ at the decoder and remover. If $C_i > +T_{clip}$ then C_i is set to $+T_{clip}$ (Step S82). If $C_i < -T_{clip}$ then C_i is set to $-T_{clip}$ (Step S84).

Whilst the example above sets $|T_{clip}|$ at 6 it may in practice have other values which may be established by experiment.

There may be no clipping at the embedder of Figure 1 in this embodiment.

However, in another embodiment, clipping is performed at the embedder. Thus the procedure of Figure 8 may be applied prior to step S1 in Figure 3 replacing C_i' in Figure 8 by C_i . The clipping is performed only for the purpose of calculating the strength parameter α_i . The coefficients C_i to which α_j P_i is added do not have clipped values.

Modifications.

As described above, the strength parameter α is dependent on the data. It may have a fixed value.

30 Other transforms

Whilst the invention has been described by way of example with reference to Wavelet transforms, it may be used with other transforms for example DCT which is an example of a spatial frequency transform.

Other material

5 Whilst the invention has been described by way of example with reference to material comprising video material (still or moving images), it may be applied to other material, for example audio material and data material.

ECC of UMID

Error correction coding (ECC) may be applied to the UMID in known manner
10 in the UMID generator 6 of Figure 1.

Other Watermark data.

Whilst the invention has been described by way of example with reference to UMIDs as the watermark data, it may be used with other data as the watermark.

Alternative calculation of modified coefficient value C_i'

15 As described above by way of example, $C_i' = C_i + \alpha_j \cdot P_i$, P_i , α_j , P_i being a modulation of the PRBS bit P_i by the bit of the UMID to be embedded. In an alternative calculation which is described in more detail in e.g. cofiled application number 00 , Attorney reference P010148GB I-00-144,

$$C_i' = C_i + \alpha_j \cdot R_i,$$

20 where R_i is the PRBS modulated by the data W_j to be embedded.

Wavelets

Wavelets are well known and are described in for example "A Really Friendly Guide to Wavelets" by C Valens, 1999 and available at www.

5 Valens shows that the discrete wavelet transform can be implemented as an iterated filter bank as used in sub-band coding, with scaling of the image by a factor of 2 at each iteration.

Thus referring to Figure 10, a spatial domain image is applied to a set of high pass HP and low pass LP filters. At level 1, the first stage of filtering, the image is
10 filtered horizontally and vertically and, in each direction, scaled down by a factor of 2.

In level 2, the low pass image from level 1 is filtered and scaled in the same way as in level 1. The filtering and scaling may be repeated in subsequent levels 3 onwards.

The result is shown schematically in Figure 9. Figure 9 is a representation normal in the art. At level one the image is spatially filtered into four bands: the lower
15 horizontal and vertical band, lH_1 , lV_1 ; the upper horizontal band hH_1 , lV_1 ; the upper vertical band lH_1 , hV_1 ; and the upper horizontal and vertical band, hH_1 , hV_1 . At level 2, the lower horizontal and vertical band, lH_1 , lV_1 is filtered and scaled into the lower horizontal and vertical band, lH_2 , lV_2 ; the upper horizontal band hH_2 , lV_2 ; the upper vertical band lH_2 , hV_2 ; and the upper horizontal and vertical band, hH_2 , hV_2 . At level 3
20 (not shown in Figure 6), the lower horizontal and vertical band, lH_2 , lV_2 is further filtered and scaled.

UMIDs

The UMID is described in SMPTE Journal March 2000. Referring to **Figure 11**, an extended UMID is shown. It comprises a first set of 32 bytes of basic UMID
5 and a second set of 32 bytes of signature metadata.

The first set of 32 bytes is the basic UMID. The components are:

- A 12-byte Universal Label to identify this as a SMPTE UMID. It defines the type of material which the UMID identifies and also defines the methods by which the globally unique Material and locally unique Instance numbers are created.
 - 10 •A 1-byte length value to define the length of the remaining part of the UMID.
-
- A 3-byte Instance number which is used to distinguish between different 'instances' of material with the same Material number.
 - A 16-byte Material number which is used to identify each clip. Each Material number is the same for related instances of the same material.
 - 15 The second set of 32 bytes of the signature metadata as a set of packed metadata items used to create an extended UMID. The extended UMID comprises the basic UMID followed immediately by signature metadata which comprises:
 - An 8-byte time/date code identifying the time and date of the Content Unit creation.
 - 20 •A 12-byte value which defines the spatial co-ordinates at the time of Content Unit creation.
 - 3 groups of 4-byte codes which register the country, organisation and user codes

Each component of the basic and extended UMIDs will now be defined in turn.

The 12-byte Universal Label

The first 12 bytes of the UMID provide identification of the UMID by the registered string value defined in table 2.

Byte No.	Description	Value (hex)
1	Object Identifier	06h
2	Label size	0Ch
3	Designation: ISO	2Bh
4	Designation: SMPTE	34h
5	Registry: Dictionaries	01h
6	Registry: Metadata Dictionaries	01h
7	Standard: Dictionary Number	01h
8	Version number	01h
9	Class: Identification and location	01h
10	Sub-class: Globally Unique Identifiers	01h
11	Type: UMID (Picture, Audio, Data, Group)	01, 02, 03, 04h
12	Type: Number creation method	XXh

5

Table 2: Specification of the UMID Universal Label

The hex values in table 1 may be changed: the values given are examples. Also the bytes 1-12 may have designations other than those shown by way of example in the-table. Referring to the Table 2, in the example shown byte 4 indicates that bytes 5-12 relate to a data format agreed by SMPTE. Byte 5 indicates that bytes 6 to 10 relate to "dictionary" data. Byte 6 indicates that such data is "metadata" defined by bytes 7 to 10. Byte 7 indicates the part of the dictionary containing metadata defined by bytes 9 and 10. Byte 10 indicates the version of the dictionary. Byte 9 indicates the class of data and Byte 10 indicates a particular item in the class.

In the present embodiment bytes 1 to 10 have fixed preassigned values. Byte 11 is variable. Thus referring to Figure 12, and to Table 2 above, it will be noted that the bytes 1 to 10 of the label of the UMID are fixed. Therefore they may be replaced by a 1 byte 'Type' code T representing the bytes 1 to 10. The type code T is followed

by a length code L. That is followed by 2 bytes, one of which is byte 11 of Table 2 and the other of which is byte 12 of Table 2, an instance number (3 bytes) and a material number (16 bytes). Optionally the material number may be followed by the signature metadata of the extended UMID and/or other metadata.

- 5 The UMID type (byte 11) has 4 separate values to identify each of 4 different data types as follows:

 '01h' = UMID for Picture material

 '02h' = UMID for Audio material

 '03h' = UMID for Data material

- 10 '04h' = UMID for Group material (i.e. a combination of related essence).

The last (12th) byte of the 12 byte label identifies the methods by which the material and instance numbers are created. This byte is divided into top and bottom nibbles where the top nibble defines the method of Material number creation and the bottom nibble defines the method of Instance number creation.

15 **Length**

The Length is a 1-byte number with the value '13h' for basic UMIDs and '33h' for extended UMIDs.

Instance Number

20 The Instance number is a unique 3-byte number which is created by one of several means defined by the standard. It provides the link between a particular 'instance' of a clip and externally associated metadata. Without this instance number, all material could be linked to any instance of the material and its associated metadata.

25 The creation of a new clip requires the creation of a new Material number together with a zero Instance number. Therefore, a non-zero Instance number indicates that the associated clip is not the source material. An Instance number is primarily used to identify associated metadata related to any particular instance of a clip.

Material Number

30 The 16-byte Material number is a non-zero number created by one of several means identified in the standard. The number is dependent on a 6-byte registered port ID number, time and a random number generator.

Signature Metadata

Any component from the signature metadata may be null-filled where no meaningful value can be entered. Any null-filled component is wholly null-filled to clearly indicate a downstream decoder that the component is not valid.

The Time-Date Format

5 The date-time format is 8 bytes where the first 4 bytes are a UTC (Universal Time Code) based time component. The time is defined either by an AES3 32-bit audio sample clock or SMPTE 12M depending on the essence type.

 The second 4 bytes define the date based on the Modified Julian Data (MJD) as defined in SMPTE 309M. This counts up to 999,999 days after midnight on the 17th
10 November 1858 and allows dates to the year 4597.

The Spatial Co-ordinate Format

The spatial co-ordinate value consists of three components defined as follows:

- Altitude: 8 decimal numbers specifying up to 99,999,999 metres.
- Longitude: 8 decimal numbers specifying East/West 180.00000 degrees (5
15 decimal places active).
- Latitude: 8 decimal numbers specifying North/South 90.00000 degrees (5
 decimal places active).

 The Altitude value is expressed as a value in metres from the centre of the earth thus allowing altitudes below the sea level.

20 It should be noted that although spatial co-ordinates are static for most clips, this is not true for all cases. Material captured from a moving source such as a camera mounted on a vehicle may show changing spatial co-ordinate values.

Country Code

 The Country code is an abbreviated 4-byte alpha-numeric string according to
25 the set defined in ISO 3166. Countries which are not registered can obtain a registered alpha-numeric string from the SMPTE Registration Authority.

Organisation Code

 The Organisation code is an abbreviated 4-byte alpha-numeric string registered with SMPTE. Organisation codes have meaning only in relation to their registered
30 Country code so that Organisation codes can have the same value in different countries.

User Code

The User code is a 4-byte alpha-numeric string assigned locally by each organisation and is not globally registered. User codes are defined in relation to their registered Organisation and Country codes so that User codes may have the same value in different organisations and countries.

CLAIMS

1. A method of embedding data in material, comprising the steps of:
producing transform coefficients C_i of the material;
5 comparing the magnitudes of the coefficients with a threshold value T ; and
producing, from the coefficients C_i and the said data, modified coefficient
values C_i' which are modified by respective information symbols of a pseudo random
symbol sequence modulated by the said data to be embedded;
wherein the said step of producing modified coefficient values does not use
10 coefficients of magnitude greater than the said threshold T and does not use the
corresponding information symbols.

2. A method according to claim 1, wherein the modified coefficients
 $C_i' = C_i + \alpha.P_i$
15 where $\alpha.P_i$ is an information symbol modulated by the data to be embedded, α
being a scaling factor.

3. A method according to claim 2, wherein α is dependent on the data.

20 4. A method according to claim 2, wherein α is of fixed value.

5. A method according to claim 1, wherein the modified coefficients
 $C_i' = C_i + \alpha.R_i$
where R_i is an information symbol P_i modulated by the data, and α is a scaling
25 factor.

6. A method according to claim 1, 2, 3, 4 or 5, wherein the said transform
is a wavelet transform.

30 7. A method according to claim 1, 2, 3, 4 or 5, wherein the said transform
is a spatial frequency transform.

8 A method for detecting data embedded in material, the detecting method comprising

receiving transform coefficients of the material;

5 comparing the magnitudes of the received coefficients with a threshold value T; and

correlating, the said coefficients with a respective symbols of a pseudo random symbol sequence to detect the said data, wherein the correlating step does not use coefficients of magnitude greater than the said threshold T and corresponding symbols
10 of the pseudo random symbol sequence.

9. A method according to claim 8, further comprising removing the said data from the said received coefficients not using coefficients of magnitude greater than said threshold T.

15

10. A method of detecting data embedded in material, the method comprising;

receiving transform coefficients of the material;

comparing the magnitudes of the received coefficients with a threshold Tclip;

20 clipping, to a magnitude Tclip, the magnitude of coefficients of magnitude greater than the said threshold Tclip; and

correlating the clipped and unclipped coefficients with a pseudo random symbol sequence to detect data embedded in the material.

25 11. A method according to claim 10, further comprising removing data from said clipped and unclipped coefficients.

12. A method comprising embedding data according to any one of claims 1 to 9 and a method of detecting the data according to claim 10 or 11.

30

13. A method of embedding data in material, the method comprising receiving transform coefficients Ci representing the material;

comparing the magnitudes of the said transform coefficients C_i with a threshold T_{clip} ;

clipping, to the magnitude T_{clip} , the magnitudes of those of the coefficients having a magnitude exceeding T_{clip} to produce clipped coefficients; and

- 5 producing modified coefficients C_i' values dependent on a scaling factor and the data to be embedded, and the scaling factor is calculated using the said clipped coefficients and the coefficients C_i of magnitude less than T_{clip} .

14. A computer program product arranged to carry out the method of any
10 one of the preceding claims when run on a computer.
-

15. Apparatus for embedding data in material, comprising:
a transformer for producing transform coefficients C_i of the material;
a comparator for comparing the magnitudes of the coefficients with a threshold
15 value T ; and

- a combiner for producing, from the coefficients C_i and the said data, modified coefficient values C_i' which are modified by respective information symbols of a pseudo random symbol sequence modulated by the said data to be embedded, wherein the combiner does not use coefficients of magnitude greater than the said threshold T
20 and does not use the corresponding information symbols.

16. Apparatus according to claim 12, wherein the combiner is arranged to produce modified coefficients

$$C_i' = C_i + \alpha \cdot P_i$$

- 25 where $\alpha \cdot P_i$ is an information symbol modulated by the data to be embedded, α being a scaling factor.

17. Apparatus according to claim 16, wherein α is dependent on the data.

- 30 18. Apparatus according to claim 16, wherein α is of fixed value.

19. Apparatus according to claim 15, wherein the combiner is arranged to produce coefficients

$$C_i' = C_i + \alpha \cdot R_i$$

5 where R_i is an information symbol P_i modulated by the data, and α is a scaling factor.

20. Apparatus according to claim 19, comprising a pseudo random sequence generator and a modulator for modulating the pseudo random sequence with the said data.

10

21. Apparatus according to claim 15, 16, 17, 18, 19 or 20, wherein the said transformer is a wavelet transformer.

15 22. Apparatus according to claim 15, 16, 17, 18, 19 or 20, wherein the said transformer produces a spatial frequency transform of the said material.

23. Apparatus for detecting data embedded in material, the detecting apparatus comprising

20 an input for receiving transform coefficients of the material;
a comparator for comparing the magnitudes of the received coefficients with a threshold T ; and

25 a correlator for correlating the said coefficients with respective symbols of a pseudo random symbol sequence to detect the said data, wherein the correlation does not use coefficients of magnitude greater than the said threshold T and the corresponding symbols of the pseudo random symbol sequence.

24. Apparatus according to claim 23, further comprising a data remover for removing data from the receiving coefficients, the remover omitting coefficients of magnitude greater than the said threshold T .

30

25. Apparatus for detecting data embedded in material, comprising;
an input for receiving transform coefficients C_i' of the material;

a comparator for comparing the magnitudes of the received coefficients with a threshold T_{clip} ;

a clipper for clipping, to a magnitude T_{clip} , the magnitude of coefficients of magnitude greater than the said threshold T ; and

5 a correlator for correlating the clipped and unclipped coefficients with a pseudo random symbol sequence to detect data embedded in the material.

26. Apparatus according to claim 20, further comprising a remover for removing data from the clipped and unclipped coefficients.

10

27. Apparatus for embedding data in material, the apparatus comprising:
an input for receiving transform coefficients C_i representing the material;
a comparator for comparing the magnitudes of the said transform coefficients with a threshold T_{clip} ;

15 a clipper for clipping, to the magnitude T_{clip} , the magnitudes of those of the coefficients having a magnitude exceeding T_{clip} ; and

a processor for producing modified coefficients C_i' values dependent on a scaling factor and the data to be embedded, and the scaling factor is calculated using the said clipped coefficients and the coefficients C_i of magnitude less than T_{clip} .

20

28. A system comprising embedding apparatus according to any one of claims 15 to 22 and detecting apparatus according to claim 25, 26 or 27.

29. A method or apparatus according to any preceding claim wherein the
25 said data comprises a UMID.

30. A method or apparatus according to any preceding claim wherein the said material comprises video material.

30 31. A method or apparatus according to any preceding claim wherein the said material comprises audio material.

32. A method of embedding data in material substantially as herein before described with reference to Figures 1, 2, 3, 4A and 4B or Figures 1, 2, 3 and 8 of the accompanying drawings.

5 33. A method of detecting data embedded in material substantially as herein before described with reference to Figures 5, 6 and 7 or Figures 5, 6 and 8 of the accompanying drawings.

34. Apparatus for embedding data in material substantially as herein before
10 described with reference to Figures 1, 2, 3, 4A and 4B or Figures 1, 2, 3 and 8 of the accompanying drawings.

35. Apparatus for detecting data embedded in material substantially as
15 herein before described with reference to Figures 5, 6 and 7 or Figures 5, 6 and 8 of the accompanying drawings.

ABSTRACTEMBEDDING DATA IN MATERIAL

A method of embedding data in material, comprises the steps of:
producing transform coefficients C_i of the material;
5 comparing the magnitudes of the coefficients with a threshold value T ; and
producing, from the coefficients C_i and the said data, modified coefficient
values C_i' which are modified by respective information symbols of a pseudo random
symbol sequence modulated by the said data to be embedded;

wherein the said step of producing modified coefficient values does not use
10 coefficients of magnitude greater than the said threshold T and does not use the
corresponding information symbols.

Alternatively, a threshold T_{clip} is set. Modified coefficients C_i' are produced
the values of which are dependent on a scaling factor and the data to be embedded, and
15 the scaling factor is calculated using clipped coefficients and coefficients C_i of
magnitude less than T_{clip}

[Figures 3 and 4]

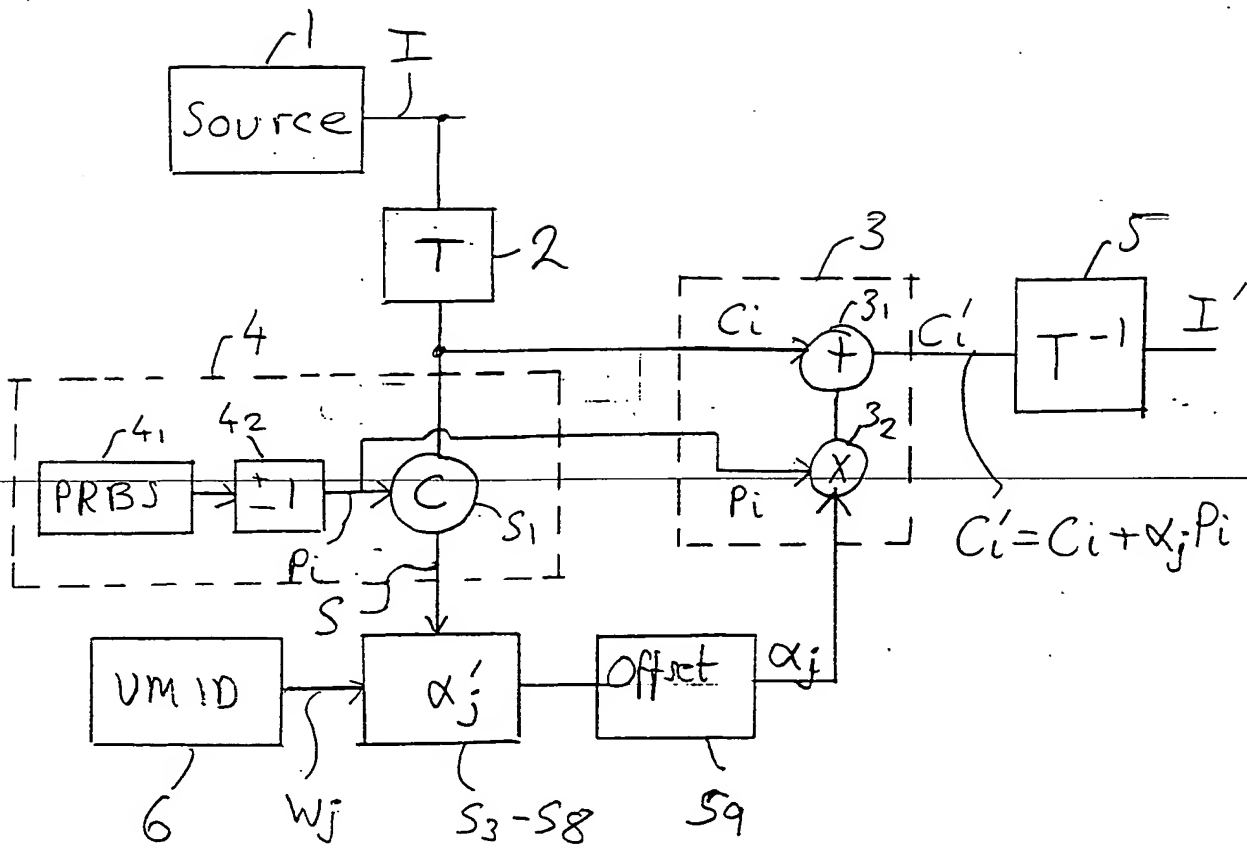


Figure 1

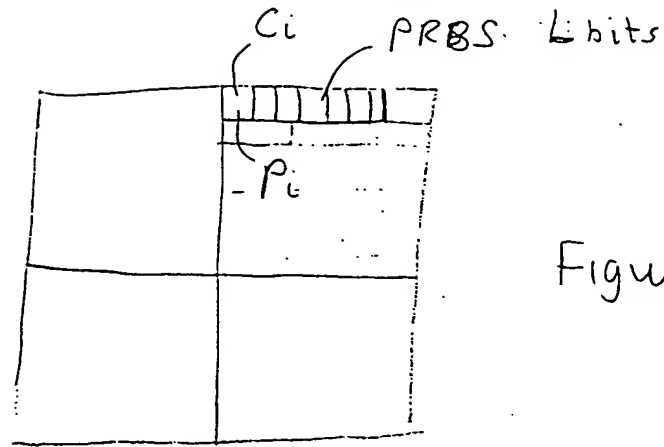
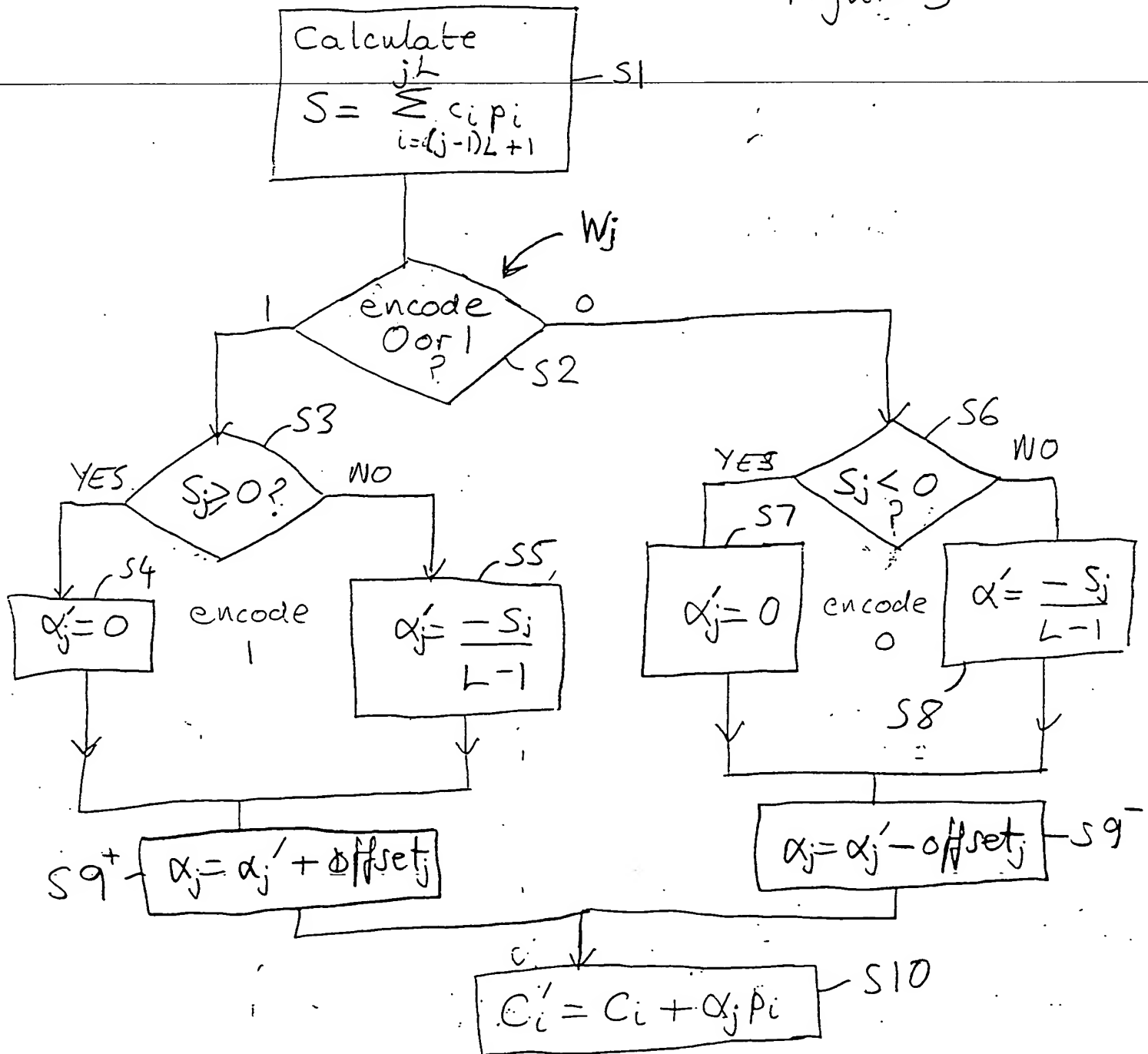


Figure 2

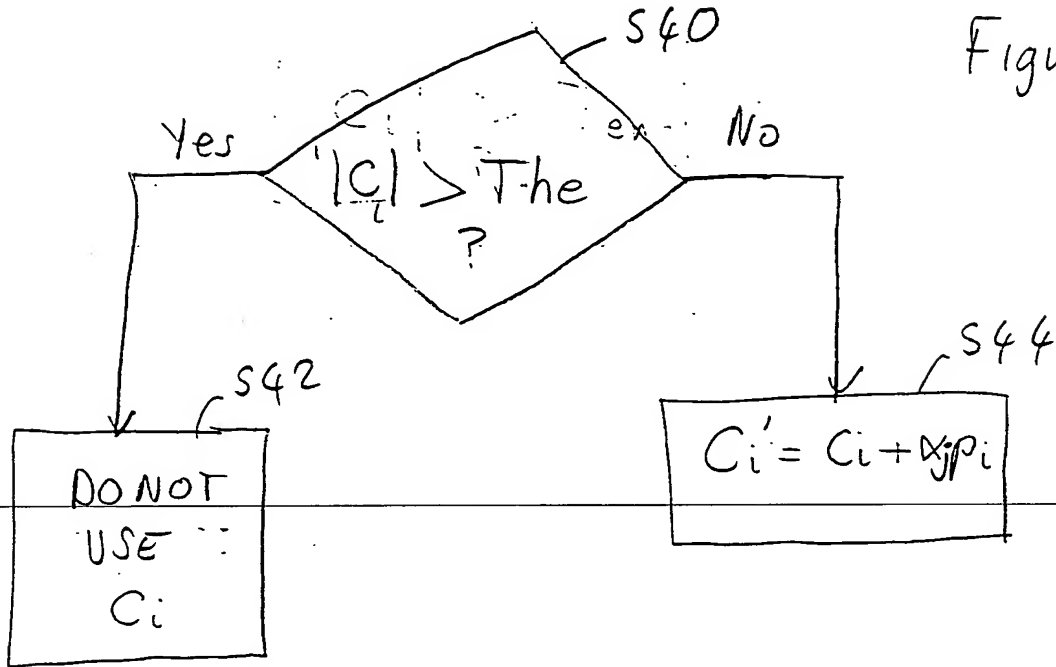
Embedder

Figure 3



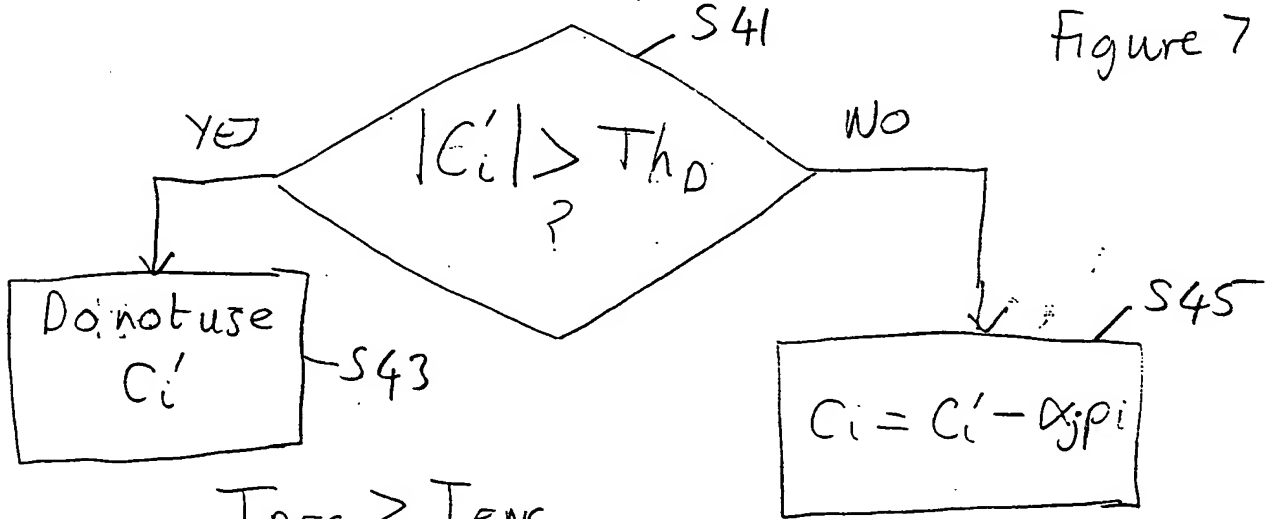
Embedder

Figure 4A



Decoder/Remover

Figure 7



$$T_{DEC} > T_{ENC}$$

$$|C_i| > T_{enc}$$

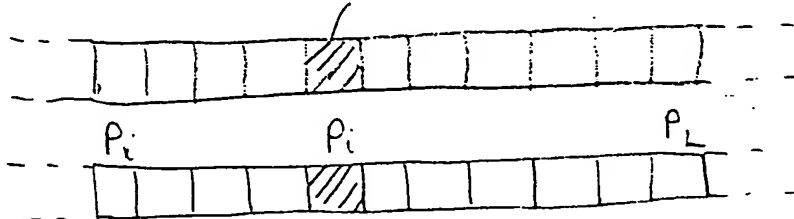


Figure 4B

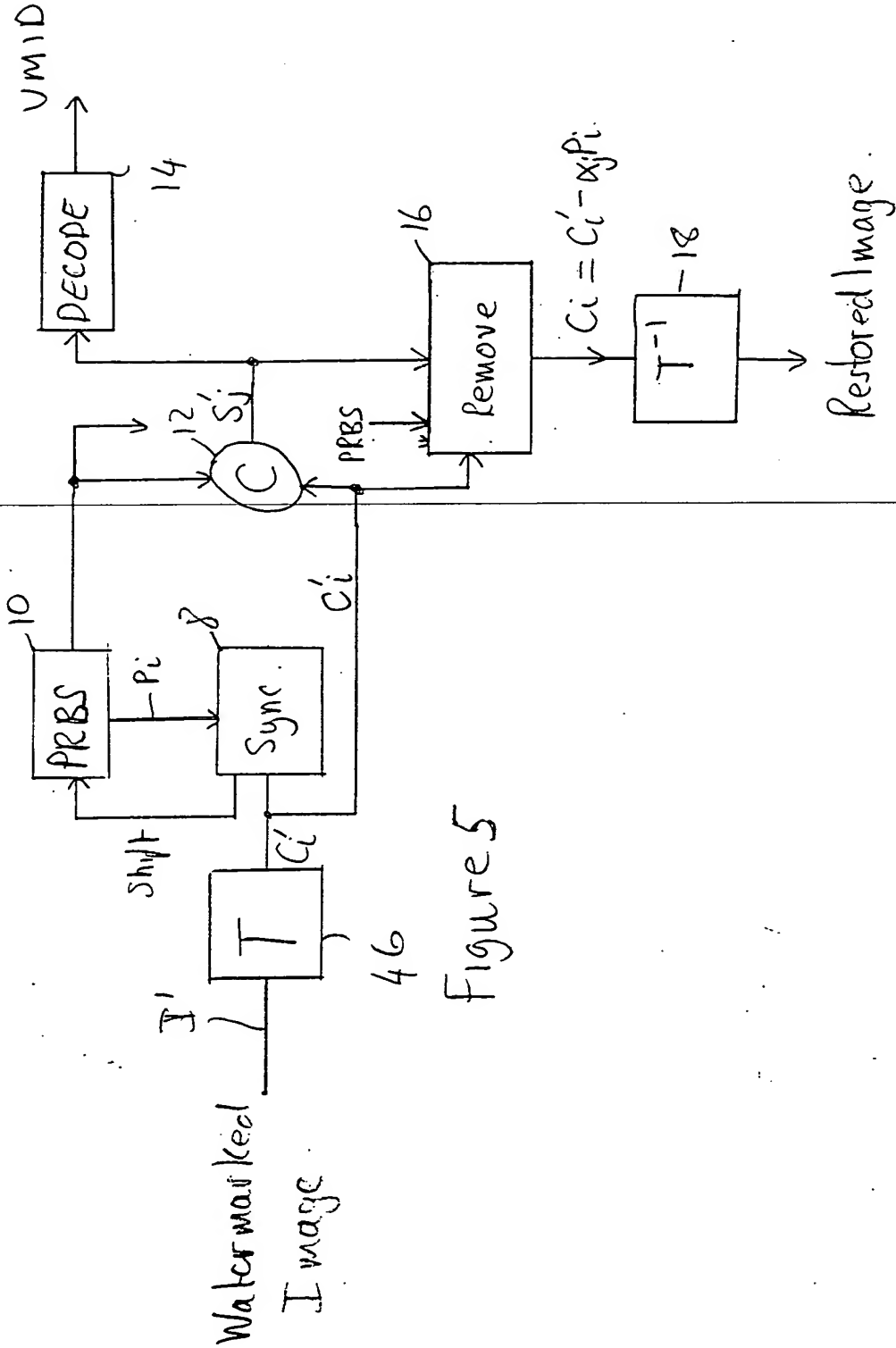


Figure 5

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I-00-84

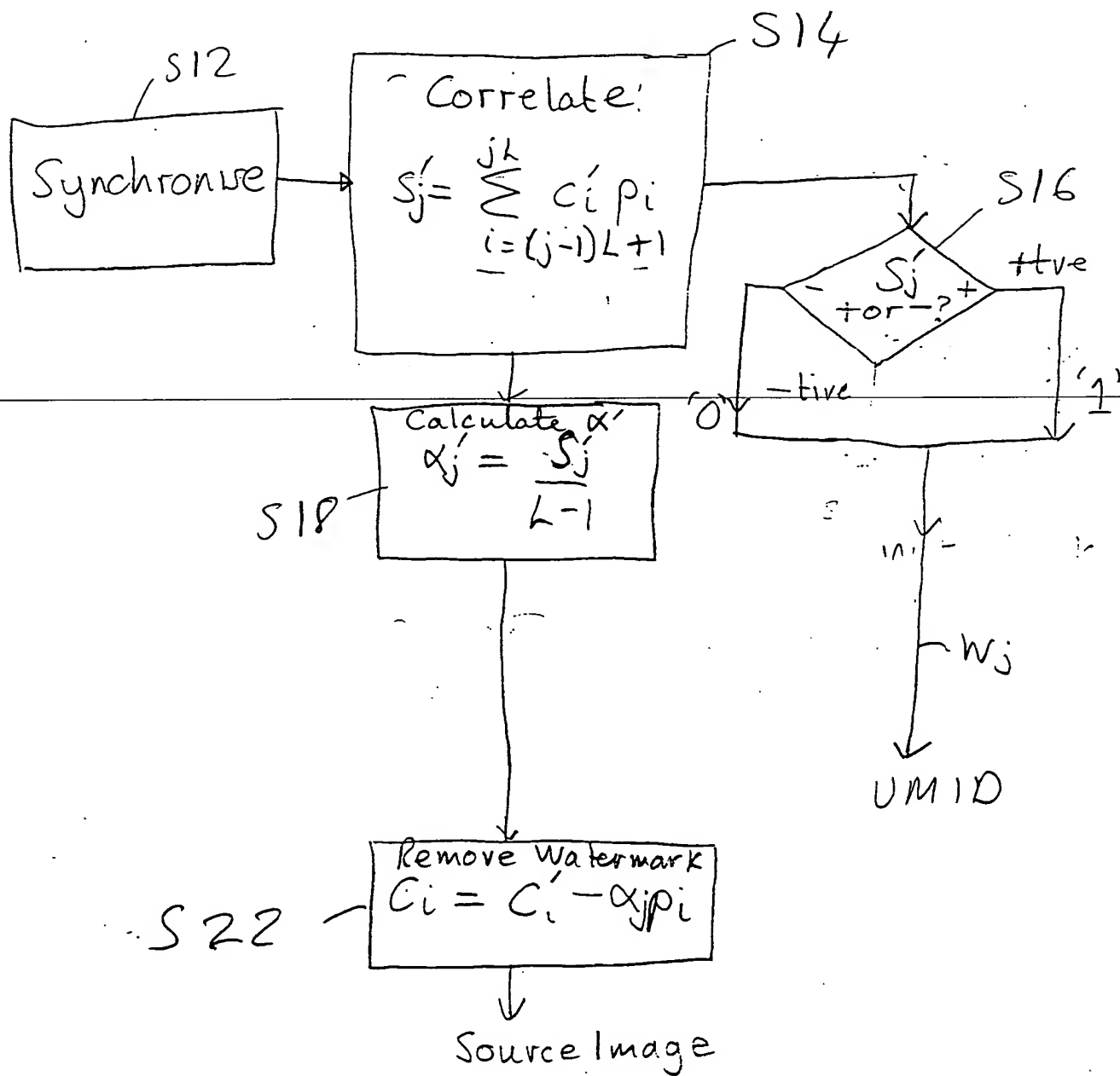
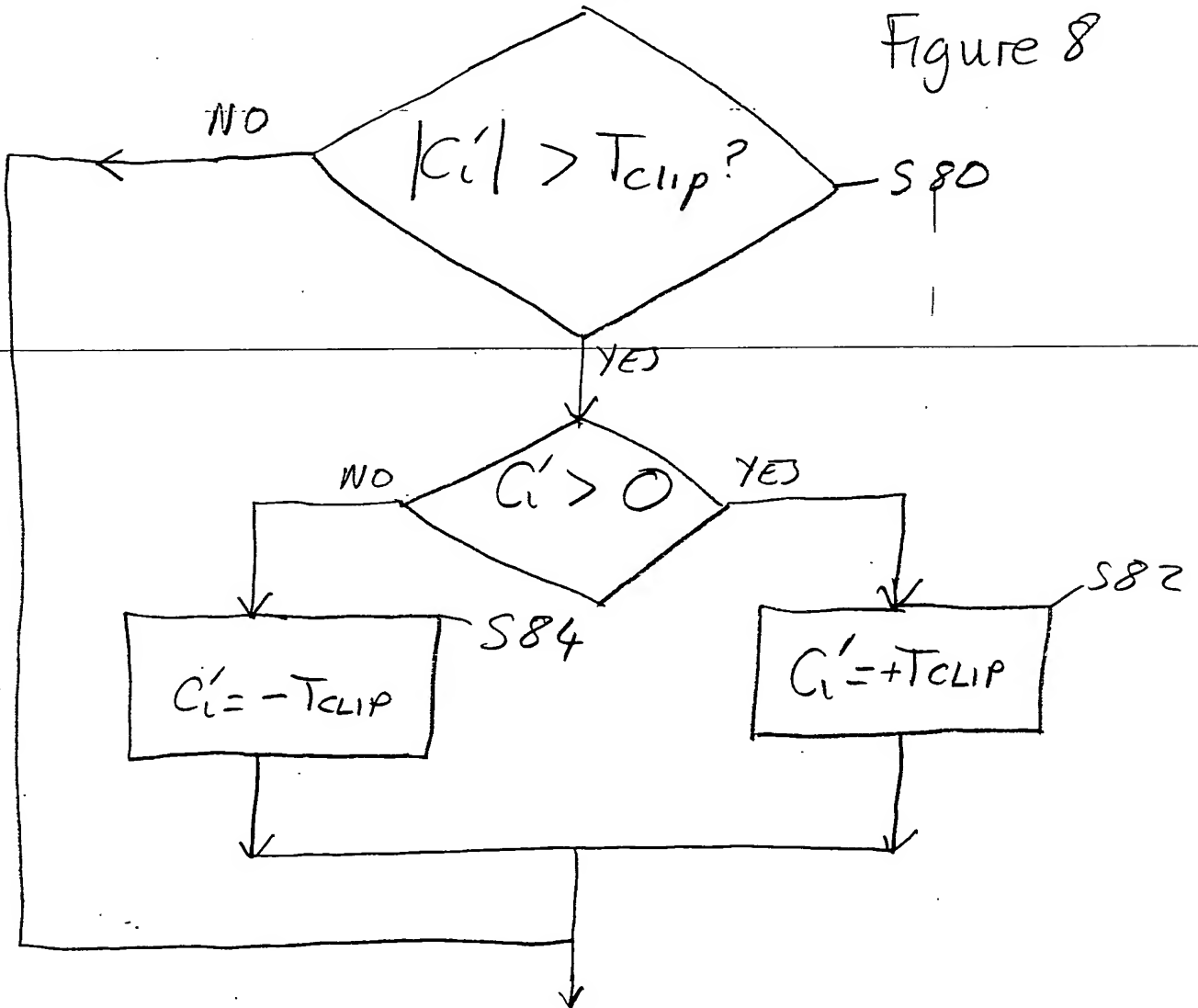
Remover and Decoder

Figure 6

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Decoder and Remover

Figure 8



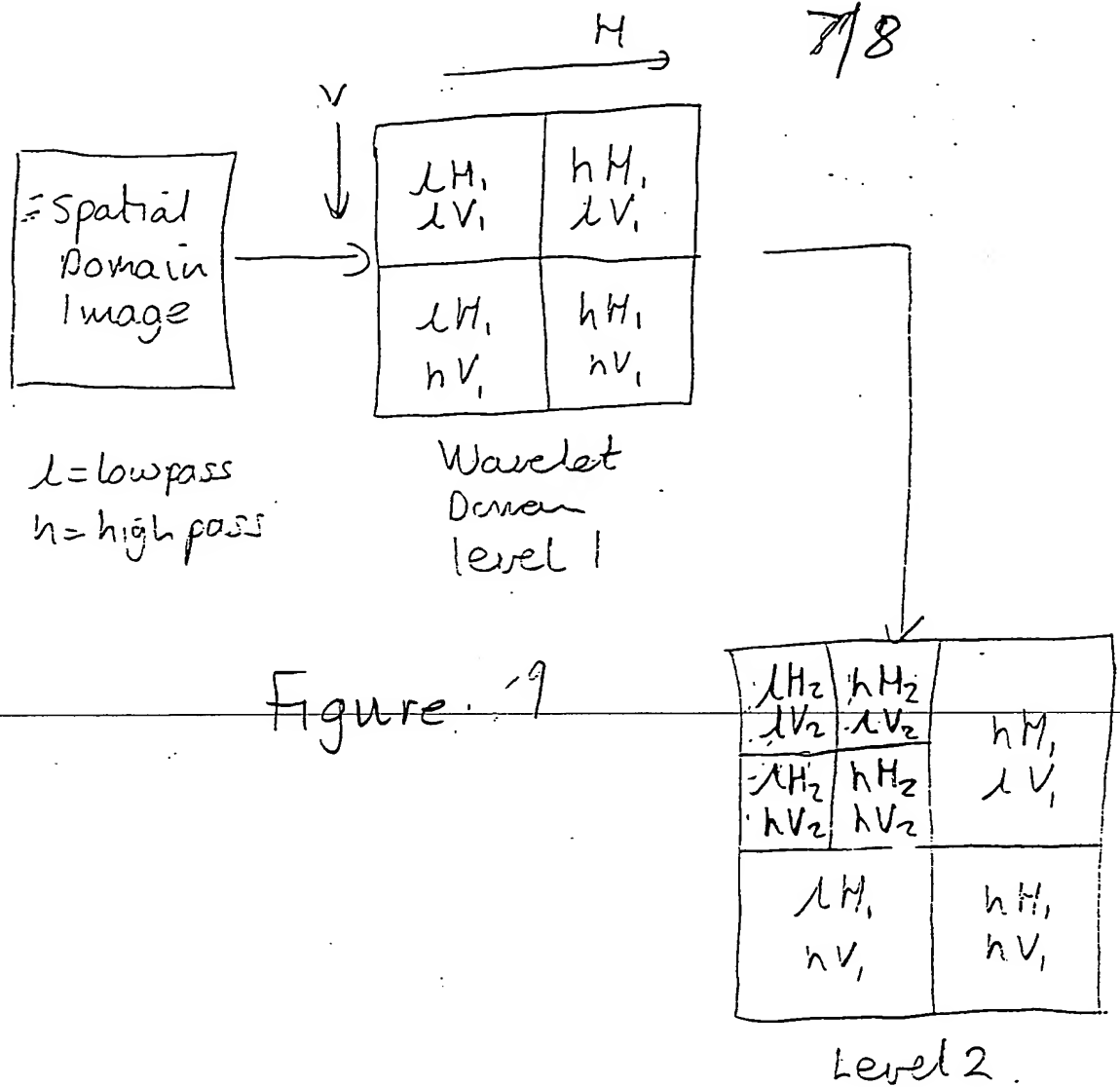


Figure 9

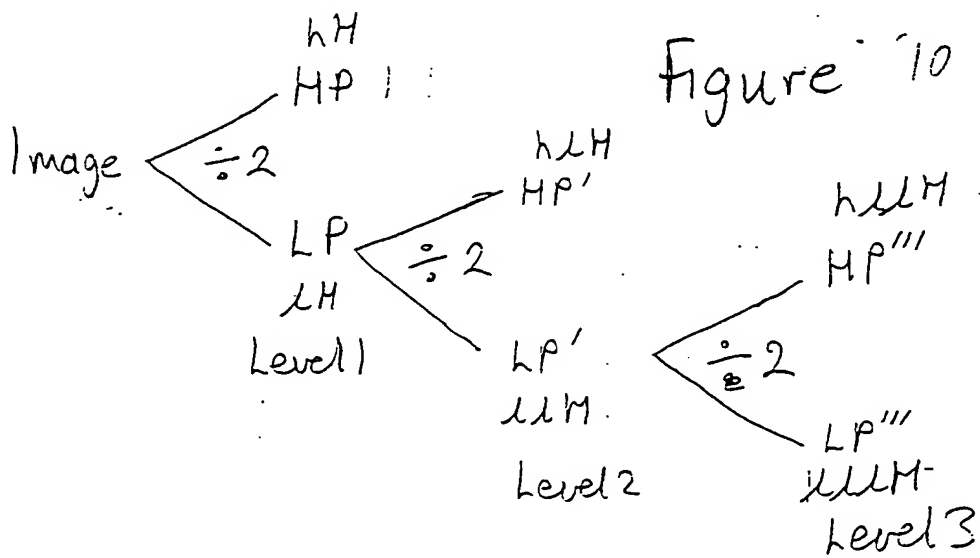


Figure 10

Schematic of Wavelet Transform.

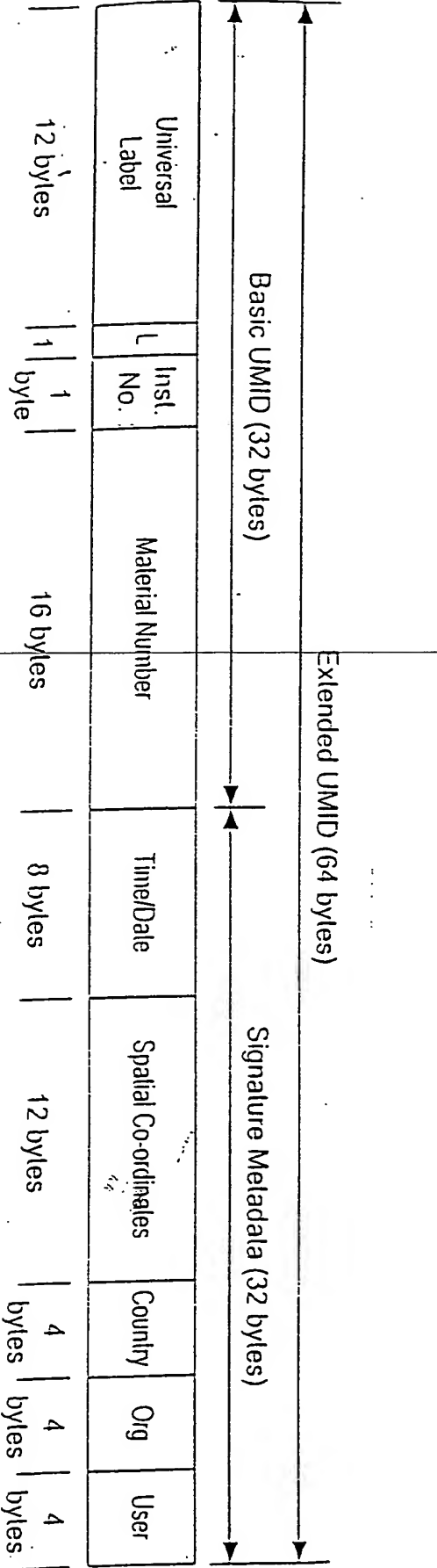


Fig. 11 Basic and Extended UMD Structures.

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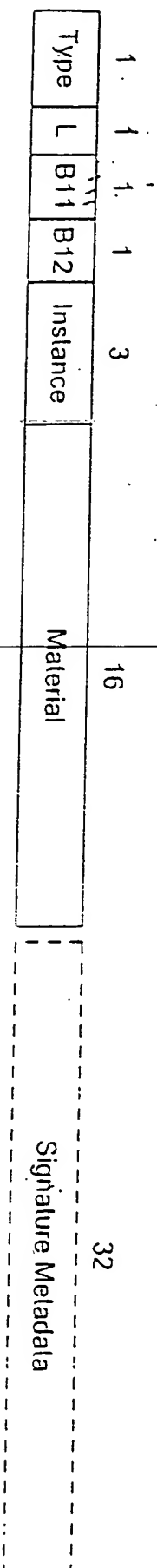


Fig. 12